THESIS

A DESCRIPTION OF AN INSTRUMENT TO ENABLE THE BLIND TO READ ORDINARY PRINT

by

Emil Leonard Ranseen

HV 1701 R

M.C. MIGEL LIBRARY
AMERICAN PRINTING
HOUSE FOR THE BLIND

c.1
HV1701
R
copy one

NORTHWESTERN UNIVERSITY

A DESCRIPTION OF AN INSTRUMENT TO ENABLE THE BLIND TO READ ORDINARY PRINT

A THESIS
SUBMITTED TO THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
for the degree
MASTER OF SCIENCE

DEPARTMENT OF PSYCHOLOGY

BY
EMIL LEONARD RANSEEN

EVANSTON, ILLINOIS
AUGUST 1936

RESEARCH
DEPT.
LIBRARY

TABLE OF CONTENTS

I. Historical Introduction - - - - - - - - - - - - - - - - - Page 1

II. A Preliminary Experiment - - - - - - - - - - - - - - - 4

III. A General Description of the Instrument - - - - - 6

IV. Details of the Construction of the Instrument - - - 7

V. Experimentation and Discussion - - - - - - - - - - - - 12

VI. Summary - 18

VII. Bibliography - 19

VIII. Acknowledgment - - - - - - - - - - - - - - - - - - - 20

IX. Vita - 21

HISTORICAL INTRODUCTION

The loss of sight is a large handicap to a human being. First of all it deprives him of what is perhaps his closest contact with the world. To a large extent, it also deprives him of access to printed matter which, in general, records mankind's greatest store of knowledge and experience. Next to the restoration of sight, a blind person's greatest wish might be to have access to the world of print.

Far back in history, letters were carved in wood or cast into type for the use of the blind. However, it was not until around 1784 that any attempt was made to teach blind persons systematically to read embossed printing. By accident a blind pupil of Valentin Hauy discovered that he could discern the outline of a letter that had been strongly impressed by printing type. Printing in relief resulted from this discovery. After this, attempts were made to find the most suitable system of print. A large number were tried and the most satisfactory has been that of Louis Braille.

Fundamentally the system perfected by Louis Braille consists of the 63 possible combinations of the six dots

• •
• •
• •

each combination standing for a letter, a punctuation mark, or a contraction of a commonly used word or syllable. The Braille system is fairly simple to print and lends itself to rapid

reading. There are about 5000 different books available in Braille, and the U.S. government contributes $100,000 yearly in furthering printing in this system for the blind. The range of reading matter is necessarily small. Only one well-known magazine, The Reader's Digest, is printed complete in Braille.

Recently phonographic records primarily for the blind have been made of reading matter. Modern methods have made it possible to record a book of 60,000 words on 8 or 9 twelve-inch, double-faced phonograph records. However, here again, although the government grants $75,000 yearly, the range of reading matter available will never be very large.

Because of the drawbacks of these indirect ways of giving the blind access to reading matter, a number of attempts have been made in more recent years to build some kind of apparatus founded on the property of selenium or of the photoelectric cell to respond differently to light and dark. Using this property to convert the black configurations on the printed page into other configurations of sound or touch, a blind person could read directly almost any printed book. Thus as early as 1914, Fournier d'Albe invented an instrument, shown in plate I, which he called an Optophone, for converting the letters of the printed page into patterns of sound.[1] As this instrument

---

[1] The Moon Element, New York: D. Appleton and Company, 1924, p.94.

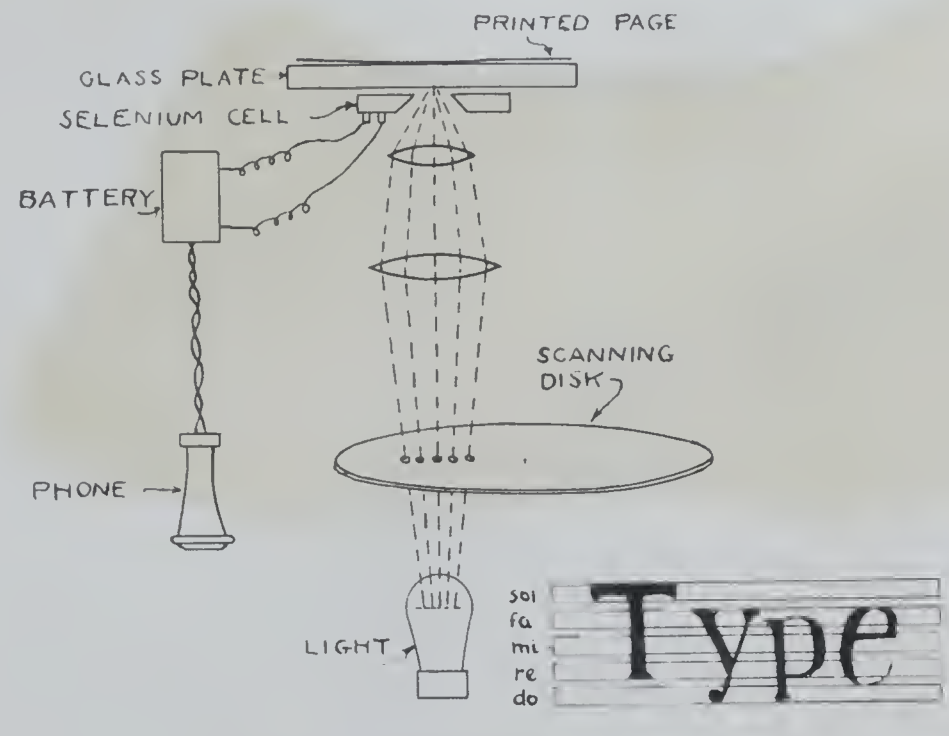
passes over the word "Type", the scanning disk with five series of holes causes intermittant light of five different frequencies to fall on a section of the letter. If a particular part of the section of the letter is black, the frequency of the sound corresponding to the position of the black part of the letter will be heard in the phone. For example, as the machine begins to pass over the letter "T", the note corresponding to sol will be heard in the phone. This note will continue until the machine reaches the stem of the "T" at which position the notes corresponding to re, mi, fa, sol will be heard simultaneously, after which the sound of sol will continue until the "T" has been passed. It is said that, after a training of 6 months, reading at the rate of 60 words per minute is possible. A similar instrument was invented by R. Rosing.[1] These instruments, for one reason or another, seem never to have been widely used. The cost, the difficulty of learning to read, and the strain connected with the reading have undoubtedly been deterring factors.

An invention by Robert Naumberg makes use of the sense of touch rather than the sense of hearing.[2] His "printing visagraph", also shown in plate I, reproduces the lines of print

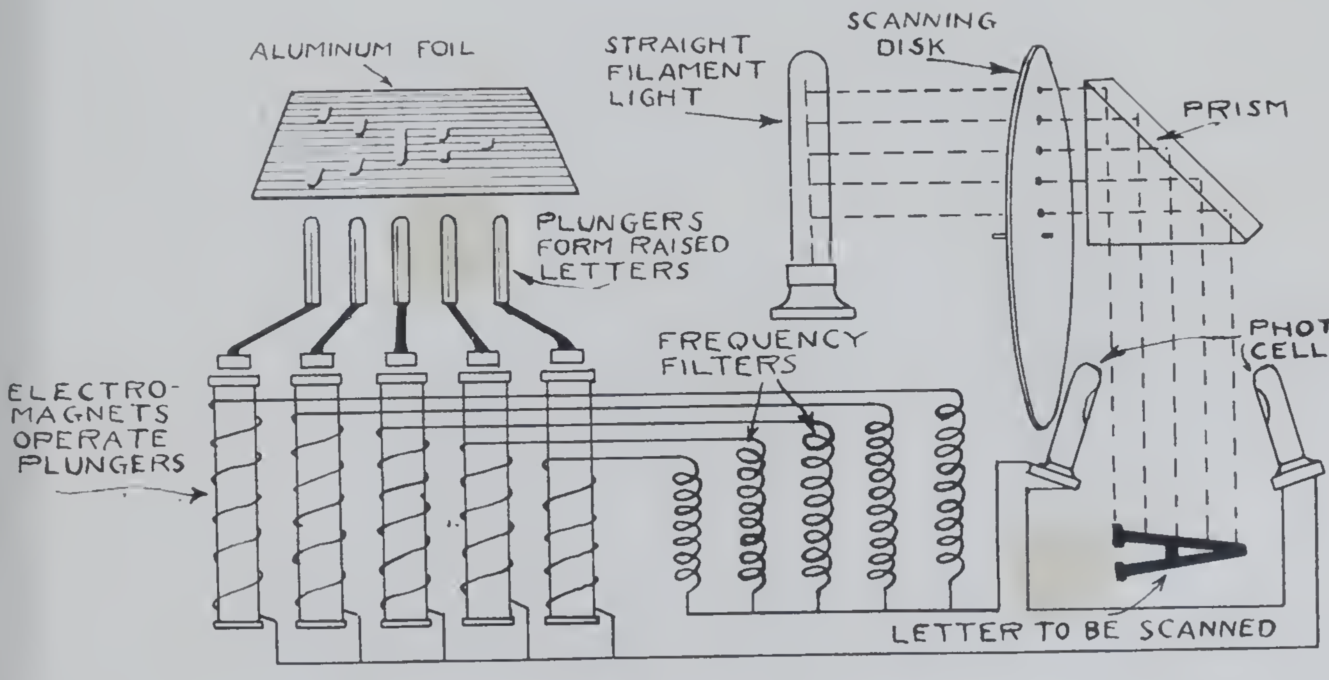
---

[1] Both the inventions of d'Albe and that of Rosing are mentioned in V.K. Zworykin and E.D. Wilson, Photocells and Their Applications, New York: John Wiley & Sons, 1930, pp. 166-168.

[2] "Art of Scanning and Reproducing Matter". U.S. Patent No.1,953,307 granted April 3, 1934.



THE OPTOPHONE



THE PRINTING VISAGRAPH

in enlarged raised characters in aluminum foil.[1] This machine operates in the following manner. The same sort of scanning disk as that in the optophone causes intermittant light of 5 different frequencies to fall of 5 parts of a section of a letter. If no black part of a letter absorbs the light of a given frequency, the resulting photoelectric current, which has the same frequency as the light, can pass through only the circuit of the electromagnet corresponding in position to the white of the paper. The plunger corresponding to this electromagnet will thus not touch the aluminum foil. Conversely, if a certain light frequency is absorbed by a black part of a letter, a plunger will rise and indent the aluminum foil in a position corresponding to the position of the black part of the letter. Thus an "A" on a printed page will result in a pattern very much like an "A" in the aluminum foil. From the point of view of reading, this instrument is perhaps the best possible solution to the problem of giving the blind access to print. Disadvantages are that the instrument is rather complicated and expensive, and the reading is not direct.

A PRELIMINARY EXPERIMENT

Before describing the apparatus by which the author has attempted to attack the problem of making ordinary print accessible to the blind, an account will be given of a preliminary

---

1. The diagram of the "printing visagraph" is from Modern Mechanics and Inventions for November 1931, p.69.

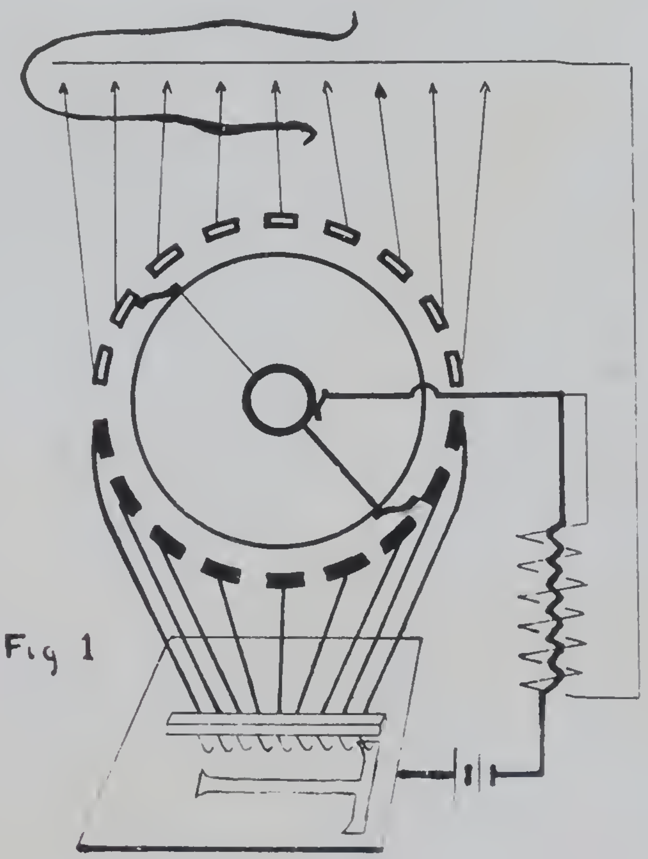


Fig 1

experiment made during the school year 1930-1931 by the writer with the assistance of Dr. Kenneth Baker. This preliminary work was done to determine if reading were actually possible by such an apparatus as the one postulated. Moreover some of the principles governing the operation of the instrument can be comprehended more easily in the simpler apparatus used in this experiment. Referring to figure 1, the letter T and the rest of the alphabet are on a brass plate with all of the brass except the letters covered with shellac. As the two brushes on the rotating wheel come in contact with the various points, circuits through the primary of the transformer are completed through those points which are in electrical connection with a wire in contact with the bare brass of the outline of the letter. When the circuit is broken, as it is from point to point, the secondary discharge of the transformer goes through a corresponding contact and stimulates a point in the hand. The discharge of a transformer is not a satisfactory stimulus but it worked well enough for the preliminary experiment. As the wire contacts are thus drawn across the letter T, the reader senses first a number of stimuli at the tip of his finger, then almost simultaneous stimuli through all the points in contact with his hand, and finally another group of stimuli at the tip of his finger. Thus, he senses a series of impulses closely resembling those he would feel were he to shield all of the hand except a narrow strip extending from, say, the tip of the long finger to the palm and then to move the hand over a large embossed letter. This experiment was successful in showing that reading could be

done in this way. However, because of the limitations of the apparatus, no satisfactory attempt could be made to study the speed at which reading might thus be accomplished. This can perhaps best be ascertained with the proposed instrument itself.

A GENERAL DESCRIPTION OF THE INSTRUMENT

The accompanying figures 2, 3, and 4 show, in the conventional front, top and side views, the machine for scanning the printed page and indicate the electrical connections whereby the hand can be stimulated at 9 different points. The whole instrument consists of three essential parts: the scanning device which rides over the printed page and converts the patterns of the letters into a set of electrical impulses, an amplifying system which amplifies and otherwise modifies the current from the photoelectric cell on the scanning device, and a third unit on which the hand rests and which is capable of stimulating the hand at 9 different points. In use the scanning unit is held upright in the hand, its weight resting on the rollers R. These rollers help support the instrument and also help guide it in a straight line so that the lens L rides directly above the line of print. The person using the instrument can keep it on the line, for he can feel any deviations from the line in the hand receiving the stimulations and can consequently bring the instrument into its proper position again with the hand guiding the scanning device.

The lens projects an image of the particular letter over which the instrument is moving onto a horizontal plane at T. Light from a narrow strip or cross-section of the letter passes

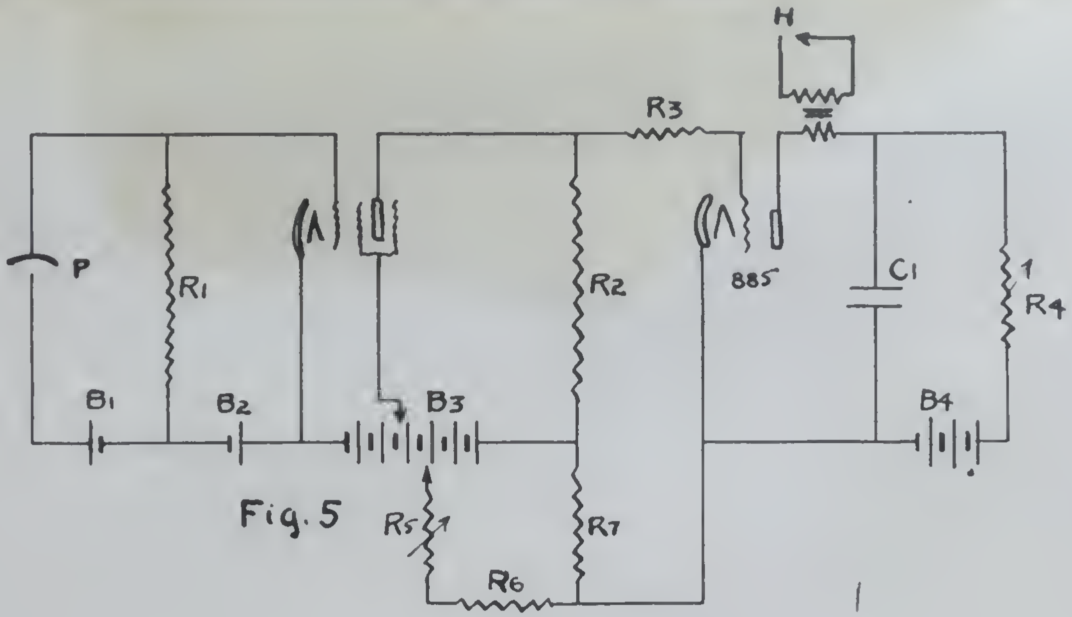


Fig. 5

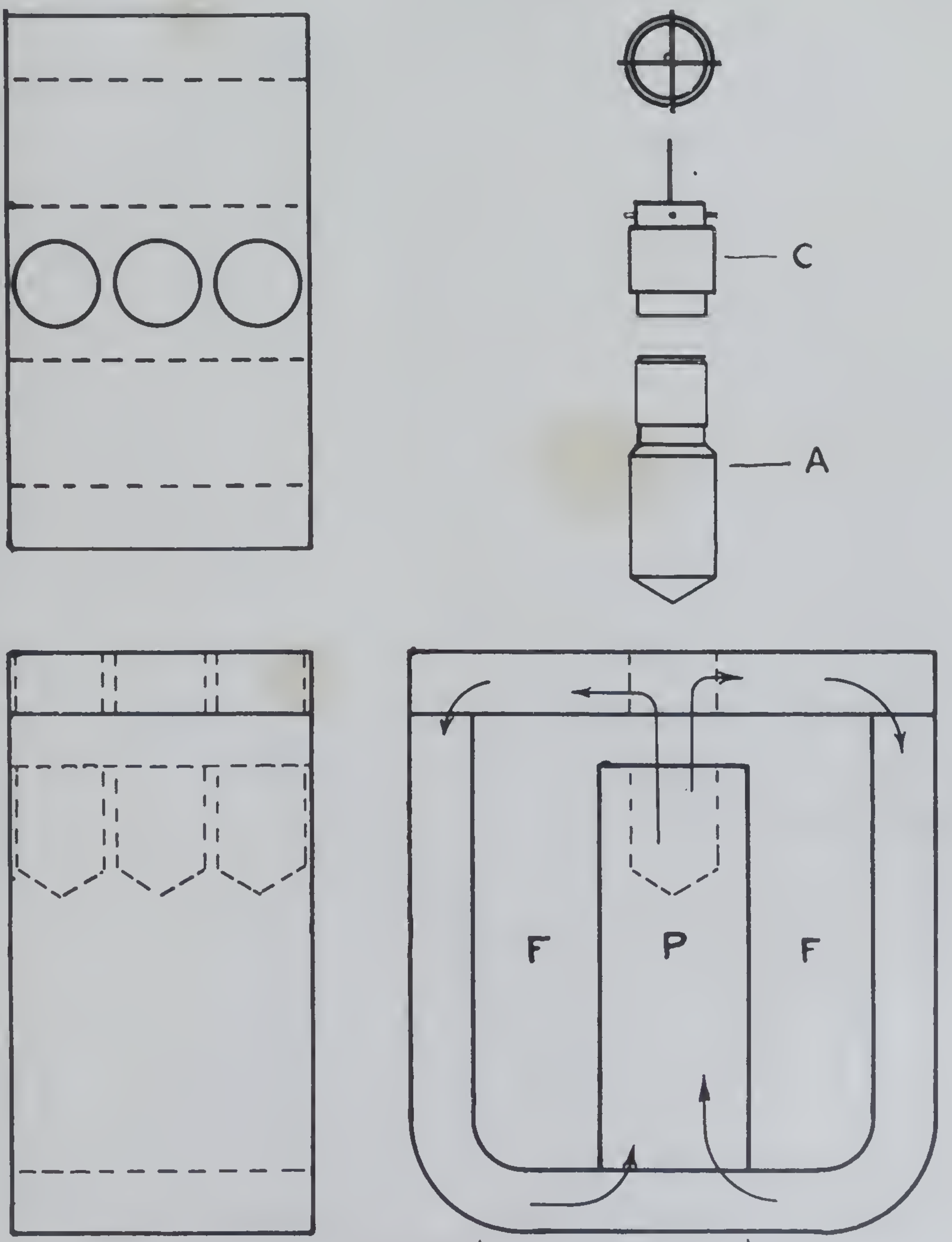
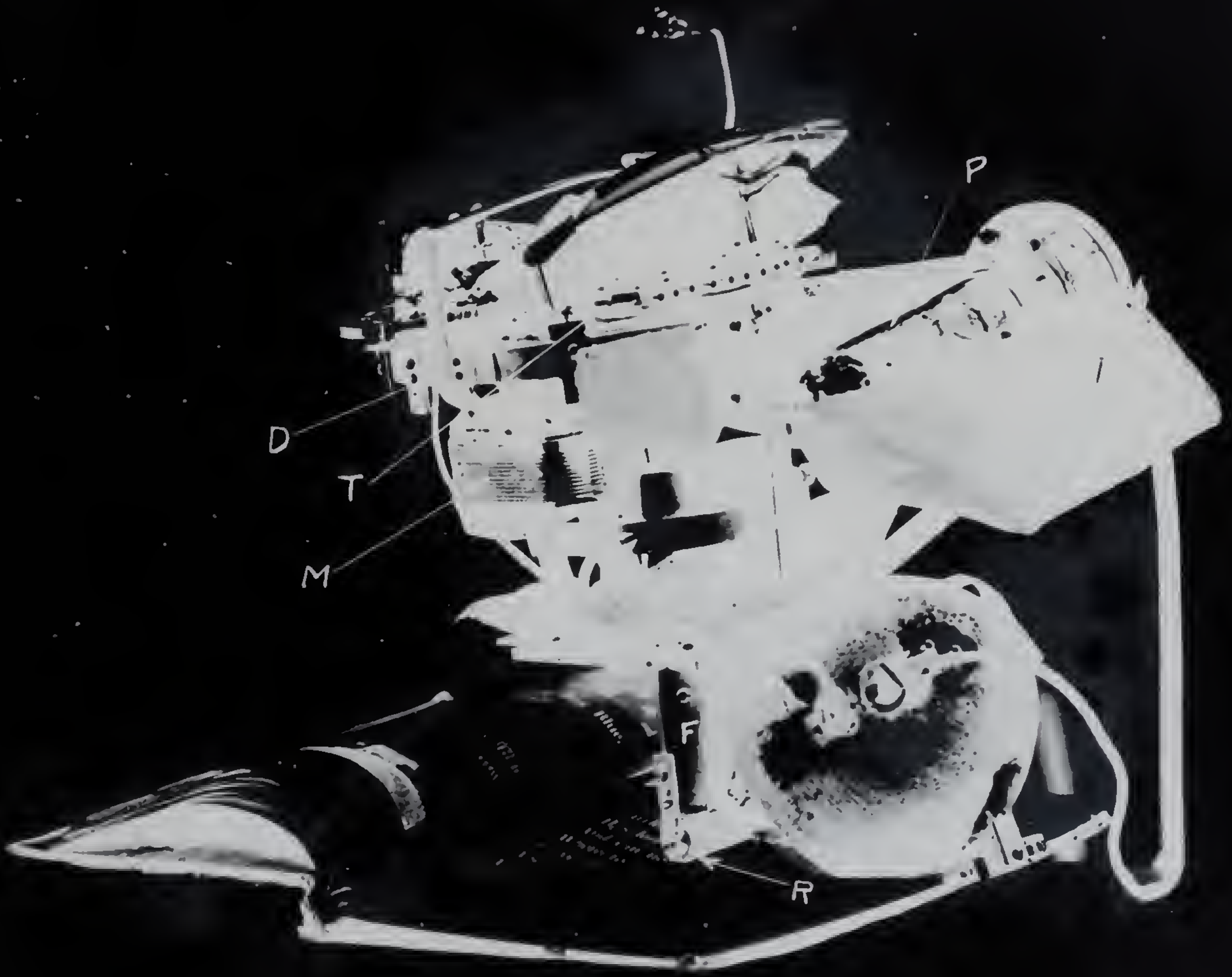


Fig. 6

through the slot T except that the moving disk D, which is turned by the motor M, cuts off all the light except that which can pass through a slot in the disk, one of which is at E. Thus, the light from a small portion of the cross-section of the letter reaches the photoelectric cell P. If this portion happens to be a projection of the black area of the letter, the photo-electric current is partially cut off. This change in current after passing through the amplifying unit results in an electrical impulse. This impulse is carried to a ring B on the moving disk of the scanning device and by means of one of the contact points K reaches a certain collector in electrical connection with a certain point at H in contact with the hand. By means of the third unit the hand is stimulated at a point at H by either electrical or mechanical means. The point stimulated will bear the same relation to the other points in contact with the hand as the selected part of the image of the cross-section bears to the whole of the cross-section. Thus as the instrument is moved along the page, the disk revolving at a fair rate of speed, the reader senses a series of impulses closely resembling those made by the instrument of the preliminary experiment. He feels the line of print as though his hand were shielded except for a narrow strip and then moved over a line of large embossed letters.

DETAILS OF THE CONSTRUCTION OF THE INSTRUMENT

An apparatus has been constructed based on the preceding general description. The scanning part is shown in the accompanying photograph. In size the scanning device is about twice that of the drawings, figures 2, 3 and 4. To illuminate


P
D
T
M
F
R

the part of the page directly below the lens, a 50 candle power automobile headlamp bulb was mounted in an ellipsoidal reflector. By this means the letter below the lens is very strongly illuminated. The illumination need not be as bright as is obtained, but the brighter illumination means that less amplification of the photoelectric current is required.

The lens, which is an ordinary double convex lens 8 mm in diameter and of 10 mm focal length, is mounted in an oblong piece of brass marked F in the drawing. To this piece of brass are mounted the rollers. The whole system of rollers, lens, and oblong tube can move in the framework so that the distance from the lens to the disk can be varied, and thus the magnification of the letters as they are projected onto the disk can be controlled.

The disk is made of bakelite. Since slots could not be cut accurately in the bakelite itself, strips of sheet copper were mounted over slots in the disk 90° apart. Then in these pieces of sheet copper were accurately cut radial slots 1/16 inch wide and having their other dimensions determined by the long slit T, see figure 3. The disk is driven by a small induction motor, M.

Above the disk is the long slit T. It was made adjustable as to width throughout its length in order that the photoelectric current could be made to be constant when the scanning device was not above a letter. This adjustment was accomplished by mounting one edge of the slit, which edge consisted of a piece of opaque paper, to a strip of rubber. The side of the rubber

opposite the paper was glued firmly to a strip of bakelite and the latter was fixed to the frame of the machine. Thus a series of screws moving against the rubber in the direction of the plane of the paper and on the side of the rubber away from the slit cause the rubber, and thus also the paper, to bulge at whatever places desired, and the proper adjustment of the slit can be easily made.

Above the slit is mounted a concave mirror which focuses the image of the lens, and thus all the light coming through the lens, on a fairly small area of a photoelectric cell. This cell is of the ordinary type mounted in projection machines. The concave mirror was made by silvering an ordinary watch glass evaporating dish.

The circuit used to amplify the photoelectric current is shown in figure 5[1]. The first tube simply amplifies the very small current from the photocell. When a black part of a letter falls on the photocell there is a resulting decrease in the negative potential of the grid of the second tube with respect to its cathode. The second tube is a thyratron type tube. Thus when the decreasing potential difference reaches a certain critical value, the circuit through the transformer which leads to H will oscillate with a period depending principally on the value of the resistance R_4 and the capacity C_1.

---

[1] This circuit was designed for the author by Dr. Noel C. Jamison of the Physics Department of Northwestern University. The values of the various parts of the circuit, which produced a fairly well-operating unit may be of interest. The resistances had the following values: R_1, 9 megohm; R_2, 100,000 ohms; R_3, 2 megohm; R_4, 10,000 ohms; R_5, 50,000 ohms; R_6, 0 ohms; R_7, 100,000 ohms. The batteries had the following voltages: B_1, 90 volts; B_2, about 3 volts; B3, 225 volts; B_4, 45 volts. C_1 has a capacity of 2 mfg. The first tube is a 24A tube; the second tube is thyratron, type 885.

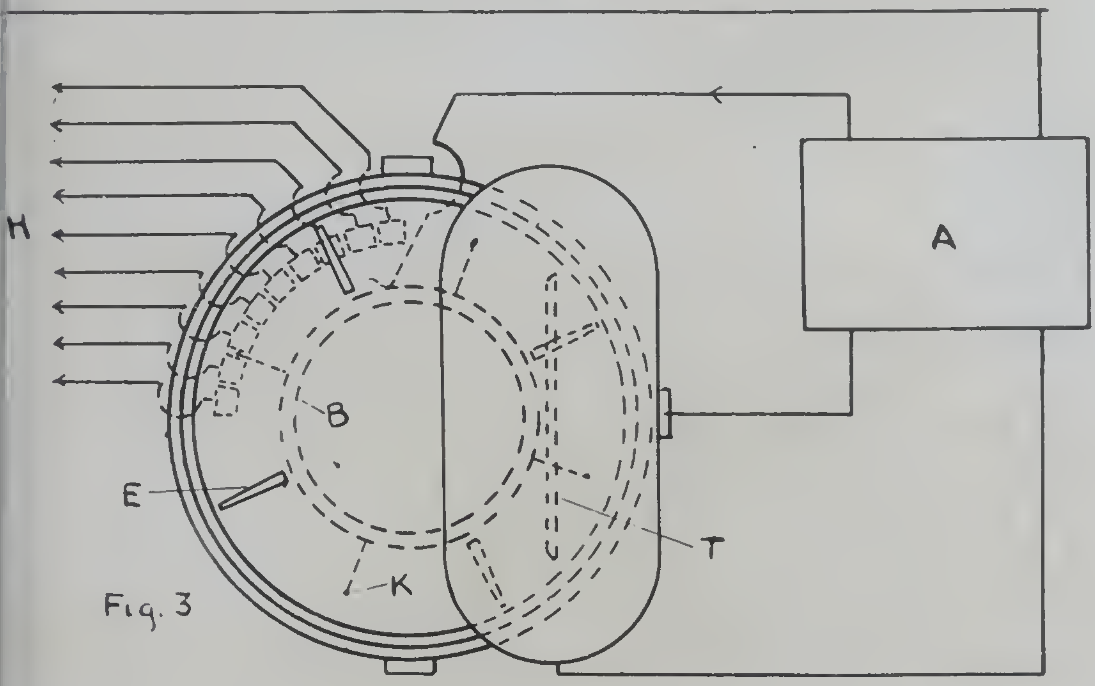


Fig. 3

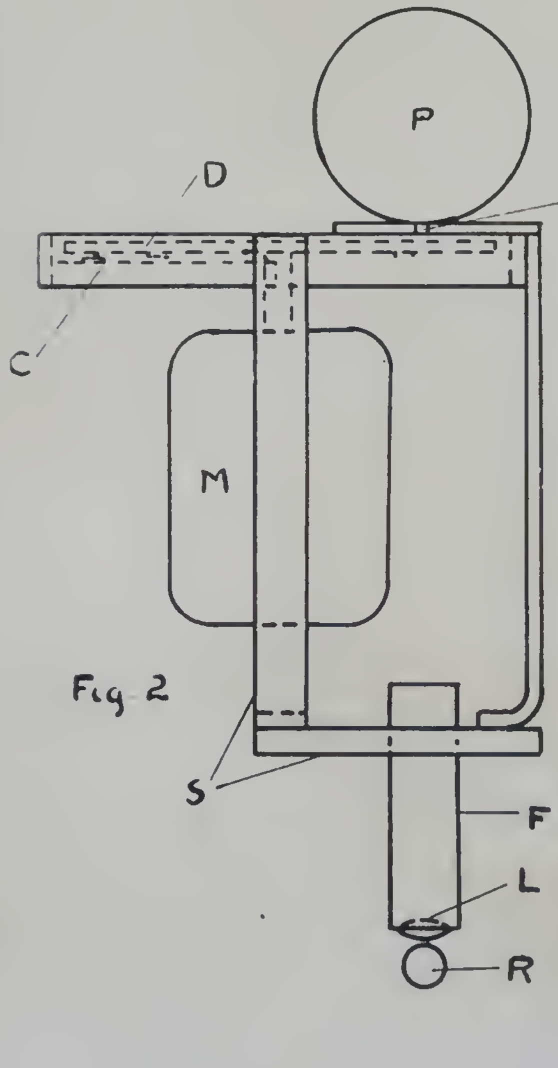


Fig. 2

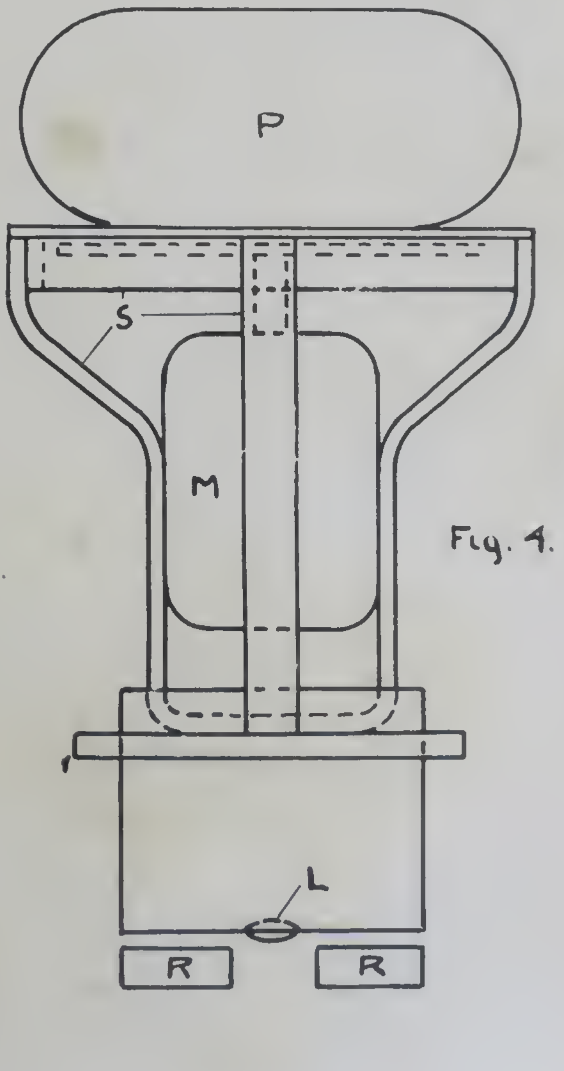
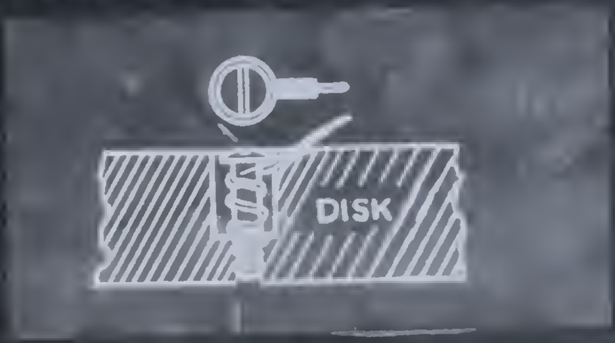


Fig. 4.

From the amplifier the current is carried to a brush which is in continual contact with the ring B, figure 3, on the revolving disk. From the ring the current is carried by wires to four points on the disk, one of which is K. These points are parts of little springs made from piano wire and are constructed and mounted as illustrated in the diagram below.



The spring has a long end which normally projects at right angles to the axis of the coil of the spring. However, as the screw is turned down into the hole, the edge of a slot in the disk, cut on the side away from the direction of motion of the disk as it revolves, causes the long end of the spring to rise above the surface of the disk. Thus the distance of the point above the surface can be closely regulated.

These points slide over a series of small blocks of phospher bronze, placed as indicated in figure 3. Thus as a slot in the disk passes over the top ninth of the long slit T, any current from the amplifier will be conducted to the lowest stimulating unit in the hand. Electrical impulses resulting from dark areas at other points along the slit are thus also conducted to their appropriate units in the hand.

The hand itself can be stimulated by the discharge of an induction coil. In this case the induction coil is placed

where a transformer is indicated in figure 5. The reading then becomes almost identical with that of the preliminary experiment. This method was given a trial, but it was not successful for one or more of several reasons. It may be that the high potential from the induction coil induced extraneous currents into the photoelectric circuit or that the discharges from the induction coil was not of uniform strength. It was deemed advisable to attempt another method of stimulating the hand which might more quickly establish the answer to the general problem of whether reading would be possible with this apparatus. A unit was therefore made by adapting the principle used in the so-called dynamic speakers in radio.

If a small coil lies in a strong radial magnetic field and if a current is passed through this coil, it will move in a direction along its axis. The unit for the hand was made up of three sections, each constructed according to the drawings in figure 6. The drawings are in full scale size. The cylindrical piece of iron A is firmly inserted in the pole piece P of the magnet. When a current flows through the field coil at F, this coil passing around the three pole pieces of the three magnetic units, the lines of flux travel around the iron circuit in the direction indicated by the arrows. Thus a strong field exists in the air gap between the top part of the piece A as it rests in the hole in P and the iron surrounding the holes. A coil of fine wire mounted on a paper cylinder, as shown in C, rests in the air gap in the magnet. Thus when an electrical impulse passes through this small coil, the coil will rise in the air

gap, and this motion will produce a touch stimulus in the hand by means of a wire rod mounted on the top of C. Nine of these coils in the three units are thus able to produce the touch pattern as previously described. Mounted above the row of coils is a board with a row of 1/4 inch holes directly above the coils. In these holes are glass beads, made from 1/4 inch glass tubing by holding an end of the tubing in a flame. These beads act as guides for the wires mounted on the coils. In use the left hand of the reader is placed over the board so that the wires coming through the beads can stimulate the hand in a line of points extending from the tip of the middle finger up into the palm.

EXPERIMENTATION AND DISCUSSION

Our primary interest has been to create a practical instrument for aiding the blind. Such a work involves a large number of problems and a compromise as to their resolution between what is best from a psychological point of view and what is practicable from a technical point of view. In order to save time and for other reasons, the preliminary psychological experimentation was often to find merely a first approximation with regard to the conditions under which the apparatus might operate. However, progress and ultimate success may wait upon more complete studies of the various psychological functions which will enter into the reading situation.

The psychological problems involved may be classified as problems of sensation, perception and learning. Under these heads will be discussed some of the preliminary exploratory work and a few of the more important problems.

The apparatus described transfers the patterns of the printed page into patterns of tactual stimuli.[1] Two methods have been used to produce these stimuli, one electrical and one mechanical. The electrical method is much the simpler of the two. In the preliminary experiment, in which this method was used, the stimulating apparatus consisted merely of an induction coil and electrical contacts with the skin. However, it is common knowledge that a current of electricity usually produces a painful and diffuse sensation rather than anything resembling a touch. However, a discharge of a small charge of static electricity of potentiality high enough to produce a spark about 2 mm in length will, if discharged in the hand, produce a sensation very closely resembling that of a light touch. There is an indication also that alternating currents of high frequency may produce such sensations also.[2] The

---

1. The machine can be adapted to producing patterns of tones similar to those produced by the optophone, and also to producing a visual pattern of very similar nature. The visual pattern would almost amount to enlarging the printing and might be helpful to the many people who have badly impaired vision. Also to such people becoming progressively more blind, the transition to reading by tactile or auditory sensation or to a combination of both might not be as difficult. To the totally blind either tactile or auditory patterns or the two in combination may thus be available. The work thus far has only been done with regard to tactual stimulation and the above discussion is also thus limited.

2. H. Koch and Y. Renquist, "Spannungsempfindung ohne Hautprickeln bei Wechselstromreizung", Shand.Arch.f.Physio., 1930, 59, pp.266-279.

discharge from the secondary of an induction coil closely resembles that of a static discharge electrically except in so far as the charge involved in the latter case is usually larger. Perhaps to this larger amount of charge is due the fact that the sensation produced by the induction coil can be painful though at different points on the skin it may not be. It is interesting to consider a reason for this peculiarity of electrical stimulation. Waterton states that the layer of epidermis which contains the end organs for tactile sensation may be shaved from the tips of the fingers without arousing pain.[1] It may be that the small amount of charge of a static discharge from a surface of very small capacity after affecting the tactile receptors may be dissipated before the charge reaches the deeper lying pain receptors. However, if the charge can follow the conducting fluid of a sweat gland, it may reach the pain receptors with enough energy to cause pain. To prevent the charge from penetrating, we tried coating the surface of the skin with graphite and putting a return electrode very close to the first. This procedure was effective in reducing and even eliminating pain when using the induction coil. Because of the simplicity of producing tactile sensations by means of electricity for this project and also for psychological studies of tactual stimulation, it may be desirable to pursue this matter of electrical stimulation further.

---

1. "On Pain", Lancet, 1933, 224, pp.943-946.

The sensations, whether produced by mechanical or electrical means, involve consideration of the location of the points whether in the hand or elsewhere on the body, the distance of these points from one another, the optimum area of the unit stimulating the skin or in the electrical case the number of discharging points over a small area which would constitute a felt point of stimulation, the intensity of stimulation, and the fatigue resulting from continuous stimulation. For the present we shall only mention these problems.

The most important problem in connection with this development is the perception of the different patterns of stimulation as different letters or groups of letters. In reading by sight from a printed page, the words are perceived as an instantaneous percept in two dimensions. In listening to reading the perception is of the temporal sequence of auditory disturbances. The form of the letter from this apparatus is built up of a spatial dimension of the horizontal component of the letter and a temporal sequence for its longitudinal dimension. It was necessary to find out whether such a sequence of sensations could be perceived as a letter or group of letters. To examine this problem, the apparatus of figure 1 was constructed. With it, Dr. Kenneth Baker and the writer experimented only enough to become assured that individual letters could be perceived with it. It was originally intended that the blindfolded subject should scan the letters on the brass sheet with his right hand and read with his left. However, this method was found to be inconvenient; so one person did the scanning while

the other blindfolded tried to figure out the letters that were passed over. When the subjects had become accustomed to the apparatus and had learned how a few of the letters felt, it was possible for them to tell what some of the other letters were by means of the apparatus alone. Of course, they knew what the shapes of the various letters were and could conceive how they might feel with the apparatus. With very little preliminary training, one of the subjects was able to read all but two or three of about 30 words by means of the electrical stimuli alone.

With the apparatus built for converting printed matter into tactual stimuli, only a small amount of exploratory experimentation has been done. With regard to electrical stimulation, the results were unsatisfactory, very likely due to imperfections in the apparatus. With magnet and coil apparatus, the author tried to distinguish the letters of two words in capital letters, THE WINDMILL. The letters W, N, M were easier to learn because the slanting in the letters produces a "traveling" sensation in the hand, and the direction of apparent movement is the cue to the letter. There was difficulty with all of the letters because of a characteristic of most printed material, which characteristic might be called the "frills" of the printed letter. An examination of almost any print will disclose the extra short lines on the stems and arms of printed letters.

It is desirable to ascertain how difficult a pattern can be perceived, and also if, with training, a pattern of greater

degree of complication can be perceived. Also it is desirable to find out what kinds of patterns are more difficult than others. The following experiment is proposed with regard to this problem of perception and learning. The capital letters of the alphabet and the numbers constitute a familiar group of forms to seeing individuals. The stimuli from the apparatus resulting from these 35 configurations and perhaps augmented by others are to be presented in haphazard order to several subjects. They are to be presented at the same rate and the same frequency. The subject will attempt to designate what the configuration is. The difficulty of the pattern will be measured by the number of times it was missed, or at what point in the presentation the subject correctly designated it, say, three out of four times. Such a study may indicate the limit of complication that can be differentiated by a subject; it may show on what elements the differentiation is based; it may show if certain groups of configurations are learned together; it will give some indication of the time necessary to learn the configurations; and it will show the rate of learning of each configuration by the increasing frequency of its correct designation. On the whole it may give much valuable information to aid in designing an experiment for the blind.

With a greater knowledge of the conditions for perception of the temporal and spatial configurations by which a blind person is to be able to read, other conditions for learning to use this apparatus perhaps will have to be studied. Consideration of these matters will be deferred until more progress has been made with regard to present problems.

SUMMARY

A blind person's best access to printed matter is by means of embossed printing, the Braille system being most widely used, and by means of phonograph recordings. Several attempts have been made to give a blind person access to printed matter in general by means of the property of selenium or a photoelectric cell to differentiate electrically between light and dark. The "Optophone" translates the printed letter into a series of musical tones. The "printing visagraph" reproduces the printed matter in enlarged and embossed letters in aluminum foil. The instrument proposed in this thesis reproduces the letters as a series of tactual stimuli.

A preliminary apparatus is described which was built to produce electrical stimuli similar to those of the proposed apparatus. A preliminary experiment showed that these stimuli could be interpreted as the letters used to produce them.

A detailed description is given of an apparatus built to reproduce the printed letters as tactual patterns. Some results with it are given and the problems involved in developing the use of it are discussed. An experiment is proposed by which to study the difficulty of the configurations by which the blind person is to learn to read.

BIBLIOGRAPHY

1. E.E. Fournier d'Albe, The Moon Element, New York: D.Appleton and Company, 1924.

2. V.K. Zworykin and E.D. Wilson, Photocells and Their Applications, New York: John Wiley and Sons, 1930.

3. Robert Naumberg, "Art of Scanning and Reproducing Matter", U.S. Patent No. 1,953,307, granted April 3, 1934.

4. H.Koch and Y.Renquist, "Spannungsempfindung ohne Hautprickeln bei Wechselstromreizung", Skandinavisches Archiv fur Physiologie, 1930, 59.

5. "On Pain", Lancet, 1933, 224.

ACKNOWLEDGMENT

The author wishes to express his appreciation for the guidance, cooperation and advice of several persons, to Professor A.R. Gilliland, under whose direction the work was done; to Professor Bartholomew J. Spence and Dr. Noel C. Jamison of the Department of Physics, without whose cooperation the instrument could not have been built; and to Professor R.G. Bigelow and Mr. M.L. West of the engineering shops.

VITA

Born - November 15, 1907.

Academic Career

Undergraduate - Crane Junior College, 1928-1930.

Northwestern University, 1930-1932.

Degree Received - B.S. Northwestern University, 1932.